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METEOROLOGY OF AUSTRALIA.

COMMONWEALTH BUREAU OF METEOROLOGY,

MELBOURNE.

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A GRAPHICAL METHOD OF SHOWING THE DAILY WEATHER, AND ESPECIALLY CLOUD TYPES.

BY

E. T. QUAYLE, B.A.
(ASSISTANT, COMMONWEALTH METEOROLOGICAL BUREAU, MELBOURNE.)

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Published under instructions from The Honorable King O'Malley, M.P., Minister of State for Home Affairs.

H. A. HUNT,
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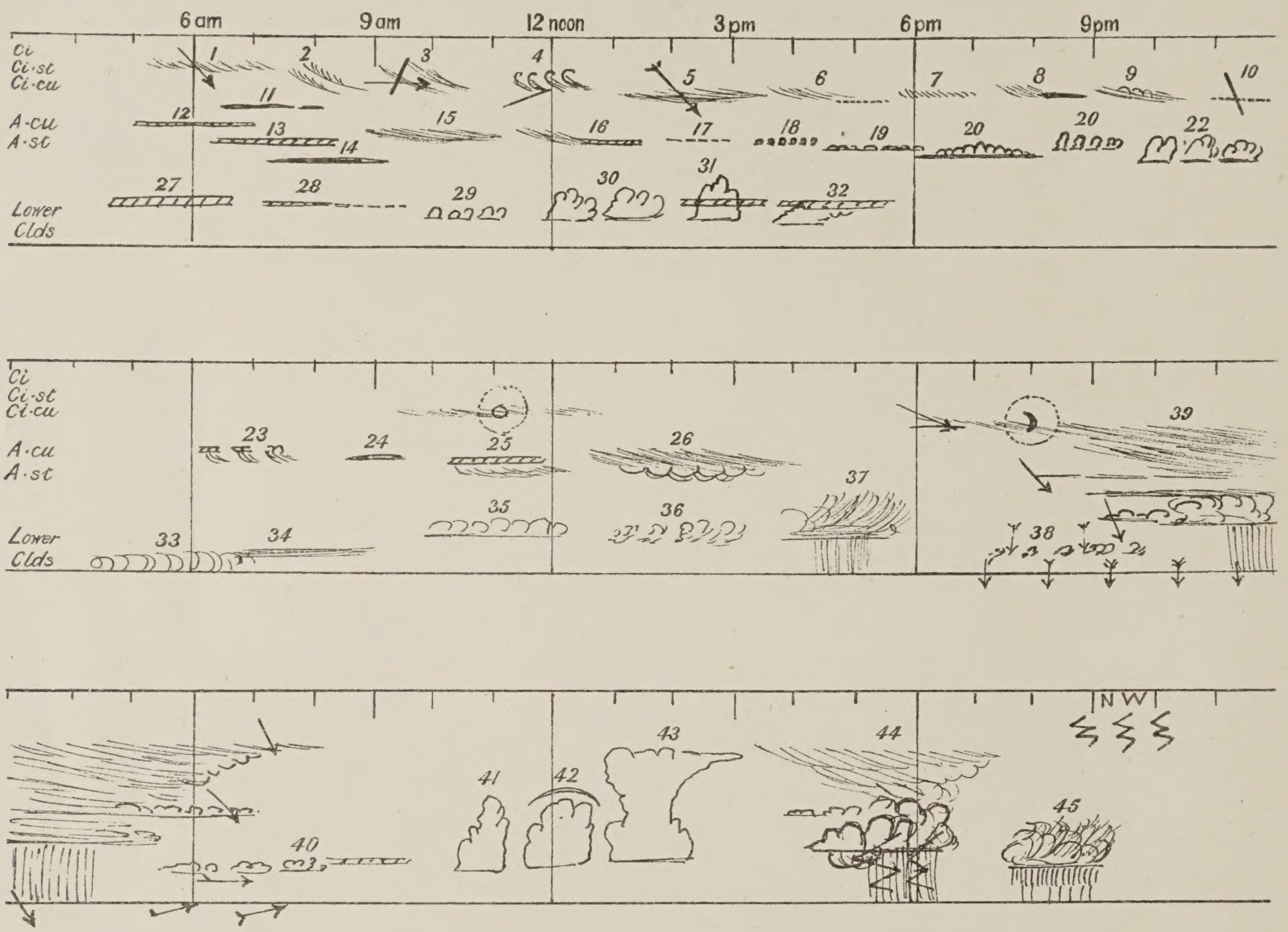
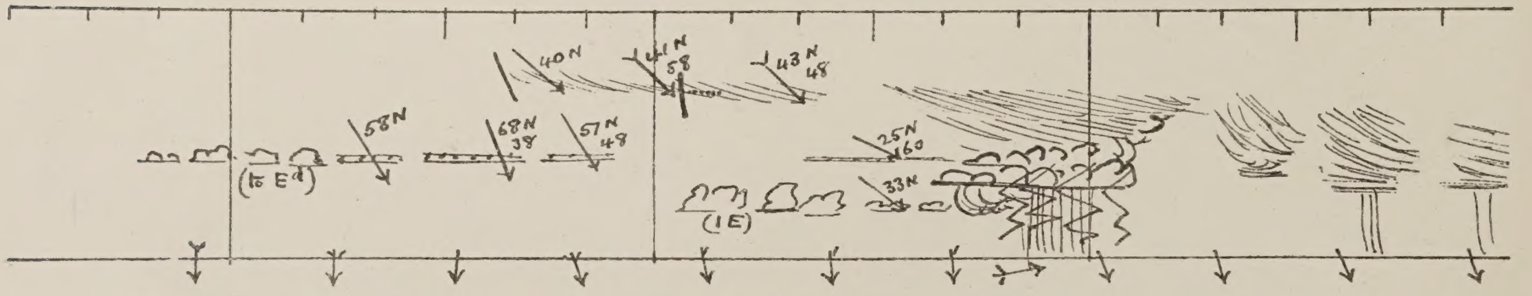
CLOUD TYPES.

Indicated by conventional sketching and relative altitudes.



EXAMPLE OF ONE DAY'S WEATHER IN MELBOURNE, SEPTEMBER 1st, 1915 (GRAPHS AND NOTES).



8.30 a.m.—Good deal of high st. cu. or low a-cu., some to eastward nicely cu fm.

10.30 a.m.—Sky nearly covered with low a-cu., and over W. to N.W. horizon thin fine-grained cirrus or ci-st., probably waved, forming parallel bars lying N.N.W.—S.S.E.

12.15 p.m.—Cirrus stripes lying N. and S., and moving from W. 41° N. ("cirrus inconstans," almost ci-cu. in places near Z, but to W^d true ci-st. with fibres all N. and S.).

2.10 p.m.—Nearly clear, but cloud bank topped by ci-st. along S.W. to N.W. horizon; cu. to E^d, interfret-like a-cu. at Z, and a little fr-cu.

4.30 p.m.—Very heavy T. storm just beginning, L very frequent, but confined to the cloud.

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A GRAPHICAL METHOD OF SHOWING THE DAILY WEATHER, AND ESPECIALLY CLOUD TYPES.

Most meteorological observers when desiring to get quickly a full and reliable impression of local weather conditions extending over a number of days, say, during the progress of a certain storm system, have been met with the difficulty of doing this from written notes. The memory finds itself wearied when dealing with even a few days, and quite unequal to the task when long periods are to be dealt with. This suggested to the writer the desirability of using some graphical method of showing from hour to hour and from day to day the variations in cloud types, their amount, direction and velocity of movements, winds, rain, electrical and other phenomena, which go to make up what we call "weather," with the result that the method here depicted was evolved, and has been in satisfactory use for a period of 27 years. The essence of the method is simply to make a rough diagrammatic pen sketch of the cloud as it would appear in section, so that characteristic features of the cloud may be indicated—an easier thing to do than one would at first think—and show the apparent relative levels of the clouds by giving a definite value to the vertical scale of the diagram. As the daily weather chart is almost indispensable for an intelligent survey of the weather, the plan was adopted of drawing a copy of it alongside the graphical representation of the daily weather. It was arranged so that each page of the book should contain the records for seven days, consequently the weather sequences for a fortnight were visible at one opening, and could be almost immediately realized in very full detail. This plan makes it extremely easy to follow the daily weather changes or refer to particular occurrences for many years back, and it is obvious, too, that it lends itself quite well to the statistical treatment of any class of phenomena.

The most cursory examination of the scheme will enable its principles to be grasped. The progress of time is shown for each day by the hour marks. The early morning hours are omitted, since little observing is possible to ordinary folk between the hours of midnight and 6 a.m., but any striking phenomena occurring then are dealt with by written notes. The cloud forms are not represented by purely conventional symbols, but practically by sketches of the cloud as seen in section or as it would appear on the horizon. In the case of clouds below cirrus level this is a very easy matter, as their lower surfaces are usually horizontal, or nearly so, and the upper usually more or less cumuliform.

The air level to which any cloud belongs is indicated by the height of its place on the vertical scale of the diagram. If we imagine this to represent, say, an extreme height of 35,000 feet, the upper fourth should be reserved for cirrus forms, which are usually at an altitude of some 5 or 6 miles (26,000 to 32,000 feet). A little more than half-way up come the various types of alto-cumulus and alto-stratus, which float at about the same altitude, say 3 to 4 miles. The lower half is taken up by clouds of lower altitude, such as strato-cumulus, ordinary cumulus, heavy clouds forming the principal rain stratum in front of cyclonic and V-depressions, &c.; and the bottom eighth by low fr. cu., scud, stratus, &c. Strict adherence to measured altitudes is hardly necessary in such a scheme even if it were possible, which, of course, it is not to the ordinary observer: what is really required is to indicate relative altitudes, and this a trained eye may easily do. For example, though two or even three forms of alto-cumulus may be seen at one time in different parts of the sky, it is not difficult to decide by their appearance which are the higher and which the lower forms. Increase in altitude is invariably accompanied by increasing refinements in form, structure, and tint, which are soon appreciated by the eye of an enthusiastic cloud observer. This fact is of very great assistance in any graphical scheme, as the same mode of sketching may be used for different types without any danger of confusing them. For example, it will be seen that ordinary alto-cumulus and strato-cumulus are depicted practically in the same way, the difference in kind being made quite evident by the plotted difference in altitude as shown by the sketching. To some extent the apparent difference in thickness, texture, and density, may also be indicated, and this is generally done. Cumulus floating at high and low levels, cirro-stratus and alto-stratus, are distinguished in the same way. It may be remarked here that the relative altitudes of the various types of cloud are sometimes difficult to determine at the zenith, especially in the case of cirrus forms, but by observing them near the horizon the differences often become evident.

The amount of cloud visible, as well as its duration, is partially indicated by the way the stratum is broken or by the addition of a figure to show numerical estimate. However, this was not a primary object with the writer.

As the diagrammatic sketches are necessarily often insufficient, they should be supplemented by short descriptive notes written underneath. For example, many details such as rippling of alto-cu., of stratiform ci-cu., and of ci-st., delicate granulations and lie of striae in cirrus, &c., cannot well be shown in such sketches.

In describing clouds, it is necessary to choose a set of suitable adjectives, each of which conveys a very definite meaning. The principal are cumuliform (cufm.), stratiform (stfm.), granular (gr.), maculated (mac.), rippled (rip.), festooned (festd.), mammillated (mam.). The additions of one or more of these to the accepted general title of the particular type of cloud will enable the observer to recall fairly faithfully at any later time what he has seen.

The direction of cloud movement and lie of the cloud stripes or bands should be shown by arrows for direction and plain bars for lie of stripe, treating the page as an ordinary map, *i.e.*, making the top north and the bottom south. Varying rates of movement can be shown by different amounts of feathering on the arrows.

The various cloud forms which the sketchings are supposed to represent, require a little description :—

(1) *Ordinary Cirrus.*—Cirrus clouds are essentially fibrous or hair-like in structure, and float at very high level. When there is no specially distinctive arrangement of the fibres, these being more or less contorted, and there is no formation of dense patches in which detail is lost, we have what Clayden* calls "Cirrus communis." (1) is intended to represent this. (The arrow shows motion from the north-west, and rate moderate.)

(2) Cirrus occasionally appears in the form of long plumes with cirriform fringes suggestive of feathers. A popular term for these is "Mares' tails," and a popular notion that windy weather is likely to follow them.

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* "Cloud Studies," by A. W. Clayden.

(3) Cirrus occasionally forms long straight parallel bands, called by Clayden "ribbon cirrus," and (3) is intended to represent this type. (The lie of the stripes is shown by the bar to be S.S.W.—N.N.E., and the direction of movement from the west, rate moderate).

(4) "*Tufted cirrus.*"—A common arrangement is the formation of soft woolly knots of cirrus from which hair-like fibres descend. These at first fall almost vertically, but are soon brushed back, often until nearly horizontal. (The half-barbed arrow shows slow movement from W.S.W.).

(5) *Cirro-stratus.*—This term simply means that the fibrous structure in the denser parts is practically lost owing to a certain thickening of the cloud stratum. Clement Ley* classes all cirrus clouds as clouds of inclination. The term is clearly correct for such forms as (4), but in cirro-stratus the inclination is not obvious. It probably exists, but if so it must be that of an inclined plane, and very gradual. The appearance of a solar or lunar halo is usually regarded as proof that the cloud causing it is cirro-stratus, the halo being due to refraction and reflection of the light by ice crystals.

The term cirro-stratus has to cover a great variety of cirriform cloud structures. The ordinary form is simply a gradual thickening and uniting into one continuous sheet of the cirrus wisps and striae which form the advance guards of an approaching storm, but under less definite conditions many other forms may appear, some of great beauty and interest. Most of these other forms have some connexion with cirro-cumulus. (The arrow shows motion from N.W., and the feathering of the arrow that the motion is fast.)

In (6) an indication is given of cirro-stratus changing into a granular structure. When the latter breaks up into delicate white discs of cloud brightly white and clearly cirriform, we have the true cirro-cumulus. The granules are usually fairly evenly spaced and sized, sometimes arranged in belts or bands, and usually move fairly fast.

(7) is intended to represent a delicate short-fibred cirrus, sometimes arranged in peculiar splashy or network formation suggestive of the mottling on marble, sometimes breaking up into minute granulations and sometimes showing most delicate rippling. This is often an evanescent and very variable cloud. Its formation is probably due to sudden diminutions of pressure at very high levels. (A diminution of pressure causes fall of temperature, and if an elevated air stratum is nearly saturated with water vapour this might be sufficient to cause condensation into visible cloud.) Clayden calls it "change cirrus."

(8) Cirro-stratus is sometimes seen to be connected with and even to originate from a perfectly sharply defined stratum or patch of cloud, the tint and structure of which show great altitude, though it is not cirriform. This might be described as stratiform cirro-stratus (stfm. ci-st.). Its relation to ci-st. is really very much like that of alto-cu. to alto-stratus. The writer on one occasion noted the appearance of a patch of this cloud near the south-western horizon, from which a belt of cirro-stratus cloud was beginning to extend eastward. The stratiform patch remained stationary, but during the next hour or two the cirro-stratus lengthened out till it reached the east-north-eastern horizon. The stratiform patch was evidently the crest of a permanent air wave—possibly due to hilly country north of Cape Otway. When it gives rise to cirro-cumulus it may be defined as stfm. ci-cu.

(9) Sometimes a dense patch of cirro-stratus (possibly alto-stratus) is seen when viewed from a distance to have a perfectly cu-form upper surface, the cumulus, of course, not hard as in ordinary types, but resembling rather masses of hair folded or bunched so as to produce the cumulus contour. The true place of this cloud is uncertain. When seen in isolated patches, the writer has usually taken it as being a form of cirro-stratus. It is then almost certainly very elevated. It is often seen well in advance of storm centres, and in a sky otherwise clear. Widespread alto-stratus occasionally shows the same formation.

(10) *Cirro-cumulus.*—This is a cloud title frequently misused. It is often taken to designate the delicate granular edges of patches of stfm. a. cu., or even of dissolving or just forming st.-cu., but this is entirely wrong. It should be confined to a granular formation at cirro-stratus level, which is either distinctly cirriform or showing granules distinctly connected with delicate cirrus fibres, and free from shading. In Victoria it is a cloud of unsettled weather, and sometimes appears closely related to (7) (the "cirrus inconstans" of Clayden). It is nearly always arranged in bands, travelling rapidly, and with its regular spacing of small white globules or discs of cloud frequently presents a very beautiful appearance. Beautifully fine granulation and rippling may often be seen with the dissipation of patches of thin stratus of upper altitudes in showery weather. (The bar shows the lie of the belts to be N.N.W.—S.S.E.).

(11) *Stratiform cirro-stratus or cirro-cumulus.*—This has already been partially described in connexion with (8). It is seldom seen independently of cirro.-st., and when it is may be taken as a lofty form of Clement Ley's "stratus lenticularis," as like most perfectly stratiform clouds of small area it is usually thickest in the centre, and thins gradually at the edges. It may be distinguished by its delicate structure, creamy tint, and obviously great altitude.

(12) *Alto-cumulus.*—Typical a-cu. is a hard cloud, not at all hair-like in structure, occurring variously as regards area from small patches to a complete sky covering, often forming bars or belts, breaking up into solid looking lumps with irregular lanes of blue sky between like ice floes in Arctic seas, or forming regular lines like furrows in a ploughed field, often changing into alto-stratus when rain is threatening, or in drier weather breaking into separate and evenly sized flakes to produce the "mackerel sky," &c. It is distinguished from strato-cumulus by greater purity of tint and delicacy in texture. Its altitude level is usually from about 10,000 to 20,000 feet. Two or even three layers of alto-cumulus may be seen in rainy weather, the highest being thin, very delicate in structure, and of a creamy tint, the lower being coarser and denser.

(13) A coarser and heavier a-cu. at lower level than the loftier a-cu. of (12).

(14) Stratiform layer at lower elevation still.

(15) *Alto-stratus.*—The front of a storm is often described as being marked first by the appearance of cirrus, which gradually changes into cirro-stratus and then again to alto-stratus by a process of gradual thickening and extension down an inclined plane to lower levels at which the term alto-stratus becomes applicable. This is not always or probably even generally true, the advent of the alto-stratus as a separate cloud not being often detected owing to its resemblance in texture to the cirro-stratus above it. In structure, alto-stratus is often hardly distinguishable from cirro-stratus, but it is really widely separated from it in altitude. Observation soon reveals the fact that it is connected with layers of alto-cumulus, and under variable conditions or slow storm development changes from a-st. to a-cu., and from a-cu. to a-st. appear in different parts of the sky. (15) is intended to show this. Sometimes when no higher clouds are present, upper portions of the a-st. appear white and almost perfectly cirriform above the a-cu., while hair-like cloud stuff continuous with it falls gradually lower so as partially to veil the lower surface of the alto-cumulus stratum.

(16) is intended to show a change from alto-stratus to alto-cumulus.

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* "Cloudland," by the Rev. Clement Ley.

(17) When alto-cumulus is fading away evenly it may sometimes leave a portion of the sky covered by thin and nearly transparent flakes fairly regularly spaced. Clement Ley calls this "stratus maculosus."

(18) A promising indication of rain is the appearance at alto-cu. level of flocks of tiny cumulus clouds, the small cumuli well separated from one another. Their small size, compactness, definiteness, and semi-globular shape, as well as a certain orderliness in their arrangement always makes these clouds attractive to the eye of a cloud student. Their appearance is likely to be followed by thunder.

(19) When alto-cumulus appears with a decidedly cumuliform upper surface and definitely stratiform bases at uniform level rain is likely to follow.

(20) *Stratus-based alto-cumulus.*—Bands of dark stratus, with cumuliform upper surface are seen often shortly before heavy rain.

(21) "*Turreted*" *alto-cumulus.*—The appearance in advance of a storm trough of alto-cu. rising into small separate cloud towers, many of which are greater vertically than laterally, is a very thundery sign. This is the cloud called by Clement Ley "stratus castellatus." The bases of these clouds are often joined by stratus, especially just before rain, so that, viewed from directly beneath, the cloud bases have the appearance of dark splashes webbed together. Towards the horizon they are seen as lines or rows of beautifully defined cumuli floating at high levels. They are often seen thus as a rainstorm is passing away eastward.

(22) *High level cumulus.*—This is only seen in thundery weather, and consists of broken masses of cumulus occasionally large enough to give a momentary shower or, in extreme cases, an occasional flash of lightning. It occurs only in very unsettled weather, generally in front of storm troughs of tropical or "monsoonal" origin. At times, however, it is practically the only rain-cloud in connexion with a rather indefinite "Antarctic" depression.

(23) "*Bearded*" *a.-cu.*—In fine weather, but probably in connexion with a very distant storm centre, detached lumps of a.-cu. may be seen from which some precipitation falls for a short distance, the effect being suggestive of a goat's beard, the whole or a portion of which is blown to one side. This is not a rainy sign.

(24) is intended to represent a type of stratification at alto-cu. level, lenticular patches dense in the centre, and thinning towards the edges.

(25) A most interesting combination is here represented. In unsettled weather and usually with an overcast sky caused by the approach of a rain-bearing disturbance a dark alto-cu. stratum may be seen veiled by a kind of festooned a.-st. The latter appears to be formed by descent of the heavier cloud particles from the alto-cu. layer above into a warmer and drier stratum beneath. The features of the under surface, which is almost mammillated, have very little permanence, and the direction of movement is usually markedly different from that of the alto-cu. layer above—in Melbourne generally 10 to 20° more northerly.

(26) *Festooned or mammillated alto-stratus.*—This only occurs in very unsettled weather. It is often seen in front of vigorous storm systems, and seems to be due to the fall of masses of moist cool air which have been temporarily carried above their proper level. These festoons and mammillations are almost always changing their forms very rapidly, as might be expected.

(27) *Strato-cumulus.*—This is a hard, dull, earthy tinted, rather coarse-structured cloud which often completely covers the sky after a storm has well passed, and when fine weather with high barometers has fairly set in. It may often be recognised by the unevenness of its under surface, which shows that it is not a true convectional cloud.

Where in an otherwise somewhat similar cloud stratum the bases are fairly level and stratiform and the upper surfaces cu. form, the cloud is really a form of cumulus, and might be called cumulo-stratus.

In Victoria strato-cumulus most frequently sets in while the centre or axis of the approaching high pressure system is to northwest of the observer, and continues while it is passing to northward. When the highest pressures are to north-east, and the wind begins to blow from that direction, the cloud bank usually clears off as one solid mass something like an immense pancake. It is usually associated with a dull light and chilly atmosphere, but may be broken sufficiently to allow of irregular lanes through which the blue of the sky is seen. Viewed from beneath the under surface is generally seen to be irregular, and in many cases the upper portions of poorly developed cumulus cloud are seen to rise into it as if feeding it. The upper surface is still more irregular, billowy without being truly cumuliform. As a matter of fact, it is a pity that the word cumulus should form part of the title. Its altitude is usually from 3,000 to 7,000 feet. It is essentially a dry weather cloud inland, though near the sea coast it may change into a low nimbus from which misty rain falls. The International Cloud Atlas has a most admirable photograph giving the "correct atmosphere."

(28) *Strato-cumulus changing to "stratus maculosus"* (Ley). When st. cu. is evaporating, and before final extinction, it forms thin semi-transparent flakes more or less disc-like, very similar to what takes place with the alto-cumulus. It often happens, too, that the formation of, or advent of, a dense bank of st. cu. is preceded by thin bands of soft maculated cloud which an inexperienced observer might take to be some form of a-cu. Its gradual change to st. cu. is usually apparent on watching for a quarter of an hour or so.

(29) *Rudimentary Cumulus.*—This consists of small detached clouds no thicker usually than strato-cumulus, but which, nevertheless, have level bases and convex upper surfaces, showing that they are caused by the condensation of moisture in rising columns of air of which they form the summit. In general, the level at which these form is slightly below that of the st. cu.

(30) *Cumulus*, the familiar form of the convectional cloud. It is very common in front of shallow depressions with slight gradients such as "monsoonal dips," and is liable to appear as soon as the high pressure centre has passed. Cumulus clouds develop best during the warmth of the day, and tend to disappear towards evening. Their persistence after sunset is usually regarded as a sign that rain is near, and is certainly a very favorable rain sign.

(31) *Cumulus rising through strato-cumulus* is not often seen. Clement Ley regards it as being a very reliable sign that rain is near at hand. As strato-cumulus is not a cloud caused by uprising currents, except as these may here and there act as feeders, its penetration by cumulus may indicate a change from anticyclonic to cyclonic conditions.

(32) *Cumulus "feeding" st. cu.*—This often produces a low, cold, dull, gray, anvil-shaped cloud, showing some mammillation in parts of its under surface.

(33) *Fog.*—This is, of course, due to chilling of the air just above the ground surface. Should the humidity be low enough, and the night clear, calm, and long enough, frost would form instead.

(34) *Stratus.*—This is simply lifted fog, and is the result of condensation of aqueous vapour due to the radiation of heat from the lowest stratum of the air. This stage is reached on clear, almost calm, nights near the ground whenever the lower air is sufficiently moist.

It may be remarked here that stratus may be formed at any level by any process of uniform cooling. For example, air nearly saturated with aqueous vapour, and suddenly relieved of superincumbent pressure, might cool sufficiently for its moisture to condense. The cloud thus formed would be true stratus. Atmospheric waves would produce similar effects, the mass of air forming the crest of the wave being cooled by release of pressure due to increased elevation. In this case bars of stratiform cloud would be produced.

(35) *Cumulo-stratus.*—This is a convenient term for widespread cloud usually seen in front of a rain area, which viewed sideways is seen to be essentially cu-form above, like ordinary cumulus or fracto-cumulus massed together, and bases all at the one level. In this respect, as well as in structure and the barometric and wind conditions of their occurrence, they differ essentially from strato-cumulus, which is associated rather with anticyclones than with the fronts of cyclonic or other depressions. The ascent in this case is not that of isolated columns of air, such as cause cumulus clouds, but a general ascent as on an inclined plane in front of storm troughs or centres.

(36) *Fracto-cumulus.*—This is the same cloud, only broken up into detached portions, and possibly torn by irregular variations in horizontal velocity with ascent, so that, though truly convectional, it is thus prevented from attaining the cumulus form.

(37) *Nimbus.*—This is a ready way of indicating cloud from which rain is falling, and which may be almost any cloud whatever. It will be noticed, however, especially on the south side of the Divide in Victoria, that the rain falling in front of a barometric depression comes from cloud strata of very different type from, and of much greater elevation than, the shower clouds in rear of the depression. The former are more stratiform and extensive, being due apparently to continuous ascent on inclined planes; the latter are either detached and of cumulus type, or when stratiform owe their rain-producing power to coastal uplift or small successive disturbances, each with its slight barometric trough and wind changes.

(38) *Scud.*—This is really incipient cumulus at the very low level possible in front of a decided storm trough, but owing to the irregularity of the air currents at its low altitude under storm conditions near the ground it cannot attain cumulus form and, moreover, usually appears to move with great rapidity. For that reason it is not correct to call it fracto-stratus.

(39) Is intended to describe the developments in connexion with an ordinary rain storm during the passage of a well-defined V-depression. The interpretation is as follows:—About 6 p.m., cirro-stratus arranged in bands lying E. and W. is observed rising from W.N.W., and about 8 p.m. this gives rise to a lunar halo. By 8 or 9 p.m., alto-cumulus clouds are added, coming from N.W. and scud (38) is seen moving rapidly from N. The winds are northerly, and freshen to forces of 5 and 6, Beaufort's scale. Clouds of lower middle altitudes thicken considerably, cumulus from N.N.W. at 9 p.m., and by 11 p.m. rain begins to fall. This continues till about 4.30 next morning. As the rain bank passes away eastward, the upper clouds on its western edge are seen to be festooned or mammillated, and are moving from N.N.W. The clouds of the rain bank are soon replaced by low fr. cu. (40), moving from West, which later tend to harden into st. cu., and the wind has veered to West by South.

SPECIAL FORMS OF CUMULUS.

(41) *Towering or thunder cumulus.*—This term may be applied to moderately large cumuli, the vertical measurements of which are greater than those of their bases. These are only seen in very thundery weather, chiefly in front of trough-like depressions of tropical or monsoonal origin in summer.

(42) *Draped cumulus.*—Under conditions specially favorable to cumulus development, some of the clouds produce immediately over their summits a curved patch of stratus shaped like a saucer, mouth downwards, so as to embrace the cloud summit. In this respect it bears a very close resemblance to the cloud cap often seen covering the summit of abrupt and isolated mountain peaks. Table Mountain, behind Capetown, often presents this feature, and the writer has seen a fine example of it on Langhi Ghiran, near Ararat. In the case of the mountain peak, the stationary cloud cap is obviously due to condensation of aqueous vapour in the nearly saturated air at the level of the mountain top, the upthrust in crossing the mountain being sufficient to cause the necessary cooling, but in the case of the cumulus cloud a slightly different explanation must be sought. If we conceive of a very buoyant column of air ascending in one mass, and a stratum above it to be nearly saturated with aqueous vapour, the heaving of portion of this stratum upwards by the ascending mass beneath would by the cooling due to lessened pressure have the effect observed.

(43) *Anvil cumulus.*—The lateral extension of the summit of a cumulus cloud is rarely noticeable except in the case of those which have reached the thunderstorm stage, or have become cumulo-nimbus clouds on a grand scale. The altitude at which the summit outspreads may be taken as marking the maximium elevation which the combined effects of the original heat and vapour contents of the ascending air column have enabled it to attain, but the spreading is often assisted by, and may be entirely due to, a considerable change in velocity or direction of movement in the air at this upper level. It is not uncommon to see the central part of the cloud column causing a distinct bulge upwards in the otherwise level upper surface. Such a cloud will always be flanked by minor cumulus masses.

(44) *Cumulo-nimbus.*—This is intended to represent a fully developed thunderstorm cloud. Such is usually preceded in Melbourne, if it is a typical summer thunderstorm, by the appearance of well developed cumulus clouds towards noon, and if it is to be on the grand scale by cirro-stratus of rapidly increasing density moving from some northerly point. When the storm is near, the massing of cumulus clouds beneath is, of course, a prominent feature, and if the barometer is to be much affected the rain will be immediately preceded by a heavy roll of "squall-cumulus." In other cases, such as extensive cyclonic depressions provide, the thunderstorm may be preceded for twelve hours or so by the cumuli form types of a-cu. already described.

(45) "*Snow Clouds.*"—Snow does not often fall on the Victorian lowlands, but in winter what might be termed snow clouds are often seen in connexion with cold snaps. These are easily recognised by the density of the precipitation from them for some distance from their lower surfaces, and the sudden thinning of this precipitation at a lower level. The density above is, of course, due to falling snow, and the thinning lower down to the melting into rain drops which occupy much less space and intercept less light.

(11), (14), (24). Nearly all clouds which are chiefly characterized by lateral extension, or occur in layers, show at times stratiform portions, the word stratiform being used to signify uniform density with absence of detail, fibrous or otherwise. These are cases of true stratus, and are due, as before remarked, to some process of uniform cooling sufficient to cause condensation of the aqueous vapour in the air. Such may be caused by radiation, as in fogs, or by cooling due to wave motion, such as may be produced by the interaction of two strata flowing in different directions, or by air flowing over irregularities of the earth's surface. The last might be called permanent waves, that is, permanent so long as the velocity, direction of movement, and humidity of the air strata affected remain unchanged. Patches of stratus, evidently of great elevation, have frequently been observed by the writer apparently stationary over portions of the Divide not more than 3,000 feet in height.

It is worth noting that isolated patches of stratus at elevations below cirrus level commonly break up into granular fragments, the process beginning at the edges. The explanation of this is probably that the patch of stratus being formed by cooling due to expansion when rising to the crest of the air waves tends to dissolve again when descending towards the trough, in which case the base layer would be the first to disappear. On the other hand, the relative warming of the air caused by the release of latent heat in the process of condensation would enable small cumulus clouds to form, and these by relative ascent would to some extent escape the warming process involved in the general descent, and remain as detached bits of the cloud. Within the cirrus altitudes the process is evidently different. Stratus of the characteristic tint and structure of very high clouds is not infrequently seen to provide the origin for genuine cirro-stratus or cirrus clouds. Cirro-cumulus probably also frequently originates in this way.

An actual example is often helpful, and below the three collections of typical forms is given a description of one day's weather, that of 1st September, 1915, in Melbourne. The graphical representation is interpreted as follows :—

The day began with fresh northerly winds and broken clouds of low alto-cu. type, which at 6 a.m. to eastward were somewhat cumuliform. A-cu. of lower levels were plentiful all the morning, moving at 8 a.m. from W. 58° N., at 9.50 a.m. from W. 68° N., and at 11 a.m. from W. 57° N. Angular velocity determinations for the two last gave 38 secs. and 48 secs. as the times required to cover 15° at the zenith. About 10.30 a.m. cirrus bands lying N.N.W. and S.S.E. appeared moving from W. 40° N. At 12.15 p.m., the direction of cirrus movement was W. 41° N., and at 2.10 p.m. W. 43° N., with velocities of 58 and 48 seconds per 15° respectively. The latter is a rather rapid rate. The cirrus stripes at noon lay nearly N. and S. Early in the afternoon moderate cumulus clouds appeared to eastward, and at 3 p.m. some poorly developed rudimentary cumulus proved to be moving from W. 33° N. Low alto-cumulus observed at the same time was from W. 25° N., with velocity 60 secs. Shortly after this, dense cirro-stratus began to come over, followed soon after by lower clouds of cu-fm. type, and at 4.30 p.m. a thunder shower preceded by the usual roll cumulus and a veering of the wind to W. by S. was in full operation. By 6 p.m., the weather was fine again, and winds veered to N.N.W., but light. The remainder of the evening was somewhat threatening, shower clouds being about, but very little rain fell.

At various times during the day descriptive written notes were made, and these are entered in the space below. These, it may be remarked, are unusually lengthy. Very often no written notes are needed at all.

HINTS ON OBTAINING ANGULAR VELOCITY AND DIRECTION OF CLOUD MOVEMENTS.

The study of the forms of clouds is of itself full of interest, and has a certain practical as well as æsthetic value ; but from a forecast point of view the greatest importance is to be attached to the direction and velocity of motion. The latter cannot, of course, be actually determined without the use of scientific instruments, but the angular velocity at the zenith is for each type of cloud well worth measuring. The angular unit always used by the writer is 15°, and the angular velocity noted is obtained from the number of seconds required by the cloud to move through this angle. Over Melbourne cirrus clouds very rarely cover this in less than 40 seconds, 30 seconds being about the limit. Anything less than 60 is deemed rapid. The time occupied by cirrus may be very considerable, but anything beyond ten minutes, or 600 seconds, may be regarded as practically stationary, and in excess of 300 seconds as of little significance, and tending to variability. Similarly each type of cloud has its range of velocities, and the student will in time find these useful guides to weather probabilities.

Besson's Comb Nephoscope and Fineman's (mirror) nephoscope are adequate for this work. The former is much the more convenient for use, but the latter has the advantage of portability. As both are fairly expensive, most observers would do without them, but a workable substitute may easily be contrived. Take a thin deal batten, say 1 inch wide and 25 inches long, and fasten a thin strip of wood, 6·58 inches, or 6 inches and 9·3 sixteenths of an inch long, to the end of this so as to form a T. If the bottom of the T is placed against the cheek bone just below the eye, the cross-piece on the top will be found to subtend an angle of about 15°. To test it, see whether 24 measures with it are required to make the complete circuit of the horizon. The cross-piece may now be divided into single degrees by lines at nearly equal intervals. It is very convenient in practice, too, to show 5 or 2½ degree intervals, which may be done by sticking pins into it. For the direct determination of angular velocities, the use of this will only give sufficiently correct results at or near the zenith. By utilizing a point nearly vertically above the observer, such as the corner of a high building or the branch of a tree, and holding the head steady, the number of seconds required for the cloud to pass over, say, 5° or 7½°, may be easily ascertained, and from this the time required to cover 15°.

For points not near the zenith, the velocities may also be ascertained if the following precautions are observed. First ascertain the direction from which the cloud is moving, and make your measurement at a point 90° away from it, *i.e.*, at right angles with it. Having determined the time required by the cloud to cover 15°, measure the altitude in degrees of the point of the cloud used, and multiply the time observed by the sine of this altitude. The value of the sine will, of course, need to be looked up in a book of mathematical tables. Since this may not be available, the following table is given :—

Table of Factors used to obtain time for cloud to pass over 15° *at Zenith, when observation made at other altitudes* 90° *away from the point from which the cloud is moving.*

Altitude.	Sine of Altitude.
15°	.26
20°	.34
25°	.42
30°	.50
35°	.57
40°	.64
45°	.71
50°	.77
55°	.82
60°	.87
65°	.91
70°	.94
75°	.966
80°	.985

Direction of Movement.

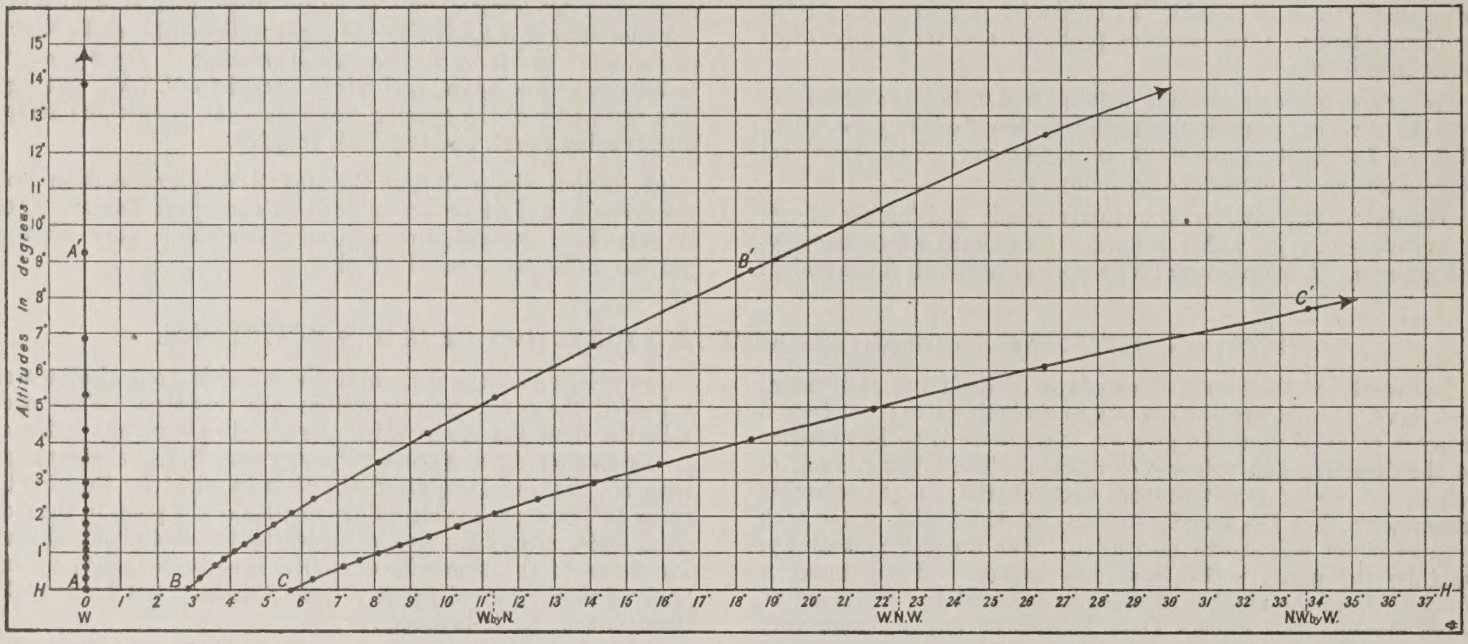
The cloud direction of movement is of the greatest importance, and care should be taken to obtain this accurately. If possible, always choose some point in the cloud which appears to be rising from or descending towards the horizon nearly vertically. Place yourself so that the cloud point is in line with some point on a high building or tree, and keeping the head steady give the cloud time to move a few degrees away from the fixed point. If now an imaginary line be drawn through the cloud point and the fixed point on the building or tree, and prolonged to the horizon, the position of this horizon point is the direction of the cloud's movement. The position of one of the cardinal points must of course be ascertained, and the T stick can then be used to obtain the distance in degrees of the horizon point noted from it.

No attempt should ever be made to judge cloud direction by merely looking into the sky. The motion of one cloud stratum gives an erroneous impression of the motion of any other. Only by reference to some fixed point, the more elevated the better, can accuracy be obtained.

Although the ordinary observer cannot be trusted to determine the horizon point from which a cloud is moving by using any but nearly vertical movements from some fixed point, a careful observer may seize opportunities and save time by observing in other positions, and still be sufficiently accurate.

Probably everyone is aware that the effect of perspective is to make bars or bands of cloud which are really parallel to one another appear to radiate from some horizon point, or to be more exact, from a point slightly below the horizon. Now it will be found that for a distance of about 30° from the vanishing point these bars or bands appear approximately straight. Hence, if by using a straight edge the apparent path of the cloud as it leaves the fixed point on building or tree is prolonged back to the horizon, and this horizon point is not more than 30° away from that part of the horizon which is vertically below the position of the cloud, it may be taken as the point from which the cloud is moving.

The graph below is intended to prove this.



Graph showing apparent successive positions in the sky of three points—A, B, and C—on a band of cloud five miles high rising from the western horizon, the alignment of these proving that observations of direction made within 30 degrees of the true horizon point from which the cloud is moving may be sufficiently accurate.

Suppose a band of cirrus cloud lying north and south to appear on the western horizon. If we assume the height of the cloud to be 5 miles, it will be just 200 miles away from the observer. Suppose the cloud direction of movement to be from due west. Assume three points on the cloud, A, B, and C, one of which, A, is due west of the observer, B 10 miles and C 20 miles due north of A. The first point, while approaching, will, of course, move vertically towards the zenith, while B and C will move towards the right. The vertical set of dots shows successive positions of cloud point A, for the 200, 180, and 160 mile distances, and then for every 10 miles to within a distance of 20 miles of the observer when the point A will be nearly 14° above the horizon. If the earth had a plane surface, the cloud when on the horizon would be at an infinite distance, and the points A, B, C, would come together, but since the earth is a sphere, the horizon distance is not infinite, only 200 miles in this case, hence B will be 2° 52′ and C 5° 42′ away from A. The lines BB′ and CC′ show the apparent paths of these cloud points, the successive dots, of course, corresponding to those on AA′. It will be seen that a straight edge applied to these lines would cut the horizon line H H in every case very near W, the true direction from which the cloud is moving. Owing to the effect of the earth's curvature, the dotted lines curve downwards when near the horizon, but they will be nearly straightened there by atmospheric refraction, which has not been allowed for in the graph. The effect of refraction is greatest on the horizon, where, for these cloud points, it will probably be from a quarter to a third of a degree, thus apparently raising the cloud by that amount, but it rapidly diminishes with altitude and for distances more than 5° above the horizon is practically inappreciable.

Hence it may be accepted that observations may be regarded as reliable if the horizon point from which the cloud appears to be moving is not more than 30° away from it as measured along the horizon, or not more than 30° away from the perpendicular dropped from the cloud. For greater distances the apparent path followed by the cloud becomes more obviously curved, and a straight edge applied tangentially to this path would give increasingly incorrect results until at 90° from the true point the cloud would be moving parallel to the horizon.

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